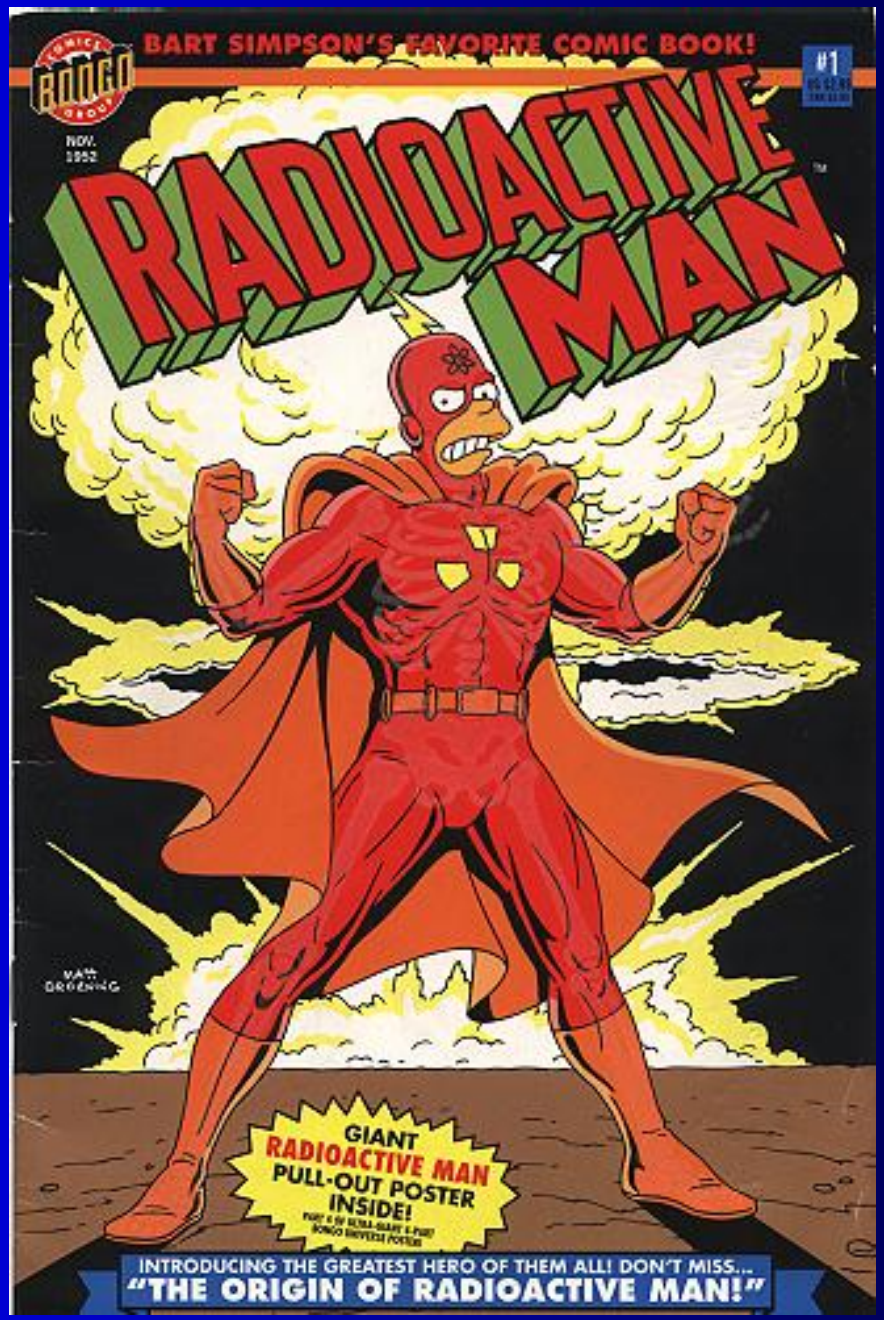
Radiation Physics and Safety

John Gough, CHP
Radiation Safety Officer

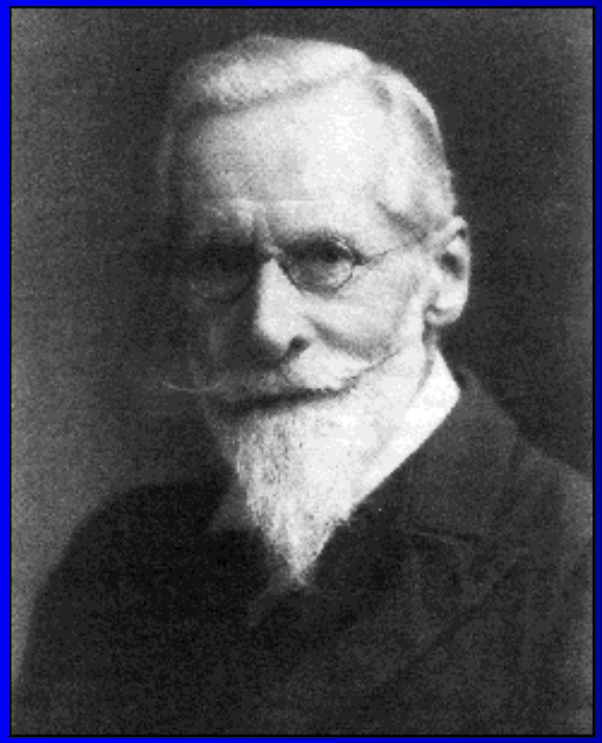

BART SIMPSON'S FAVORITE COMIC BOOK!
BONGO COMICS GROUP
NOV. 1992
#1
RADIOACTIVE MAN
MATT GROENING
GIANT RADIOACTIVE MAN PULL-OUT POSTER INSIDE!
INTRODUCING THE GREATEST HERO OF THEM ALL! DON'T MISS...
"THE ORIGIN OF RADIOACTIVE MAN!"


CAUTION
RADIATION
AREA

Outline and Objective

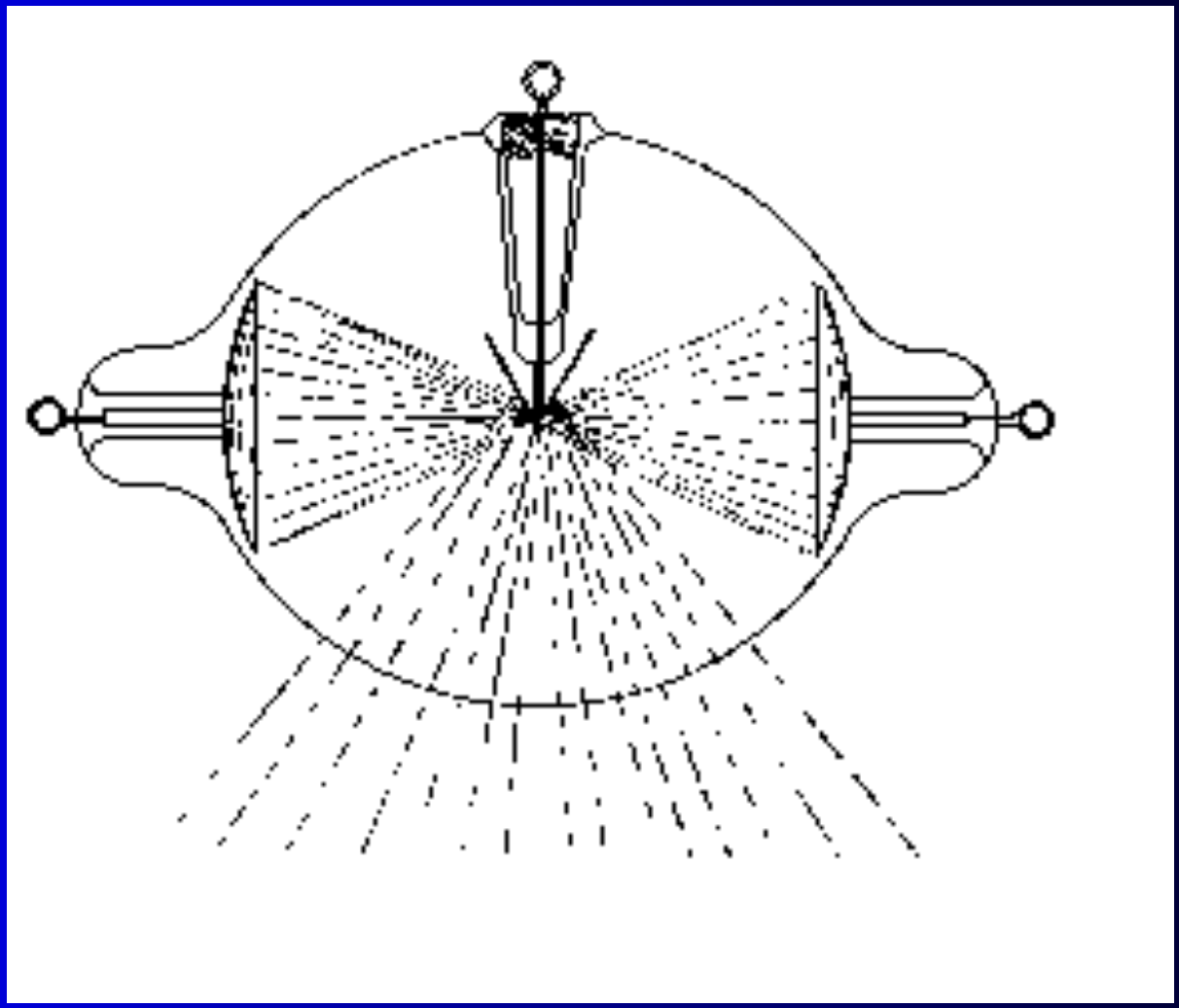
- A Brief History
- Basic Atomic Physics
- What is Radiation?
- What is Radiation Safety?
- Terminology
- Background Radiation Levels
- Radiation Exposure from Common Activities
- Health Risks Associated with Radiation Exposure
- Radiation Dose Limits and Recommendations
- Radiological Emergencies and Response
- Contact Numbers

X-ray “Pre-history”



- 1869 William Crookes notes fogging of photographic plates in his laboratory and complains of defective packaging.
- This is caused by x-rays, which were unknown at the time and produced by Crookes Tubes in the laboratory.

Crookes Tube

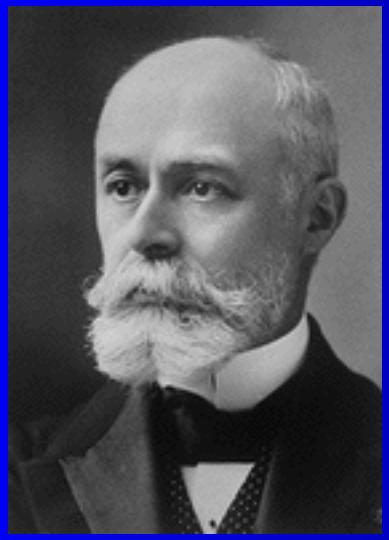


Roentgen's Discovery

- On November 8, 1895, Prof. W. Roentgen noted that the discharge from a Crookes tube or similar CRT (Cathode Ray Tube) resulted in fluorescence from a nearby paper screen covered with barium platinocyanide.
- Exhaustive research resulted in a paper published in December 1895 describing the unusual penetrating properties of this radiation.

Fig. 1. X-ray image of a hand, believed to be that of Frau Roentgen, made by W. C. Roentgen on 22 December 1895. (Reproduced from *The Rays* by R. and E. Brecher with permission from The American College of Radiology Foundation.)

Frau Roentgen's Hand



Radioactivity & Henri Becquerl

- Set about to find a natural source of these mysterious “x-rays” discovered by Roentgen.
- Discovered in March 1896 that a sample of natural uranium sulfate emitted some form of energy that would also fog photographic film without the addition of external energy.

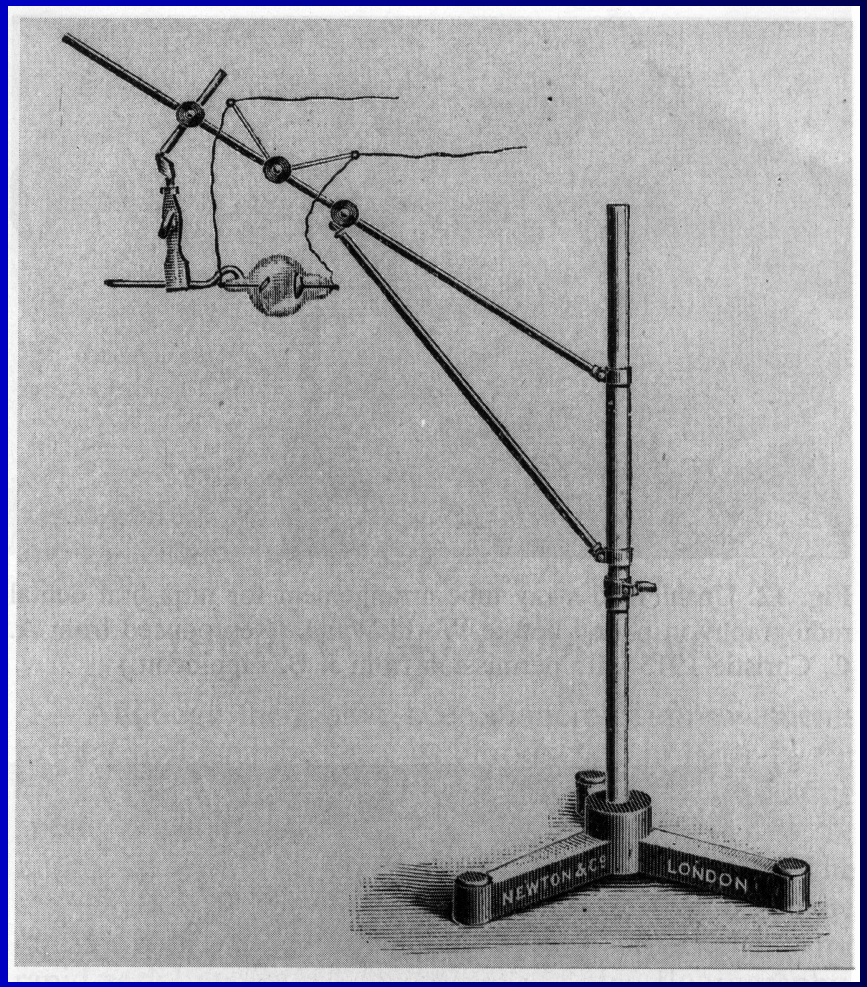
Marie & Pierre Curie

- Isolated Radium from a sample of Uranium in 1898
- Verified that when sufficient quantities were in contact with the skin it would cause a burn and then a more serious wound.
- Pioneered the use of Radium for radiotherapeutic treatment of tumors and other malignancies

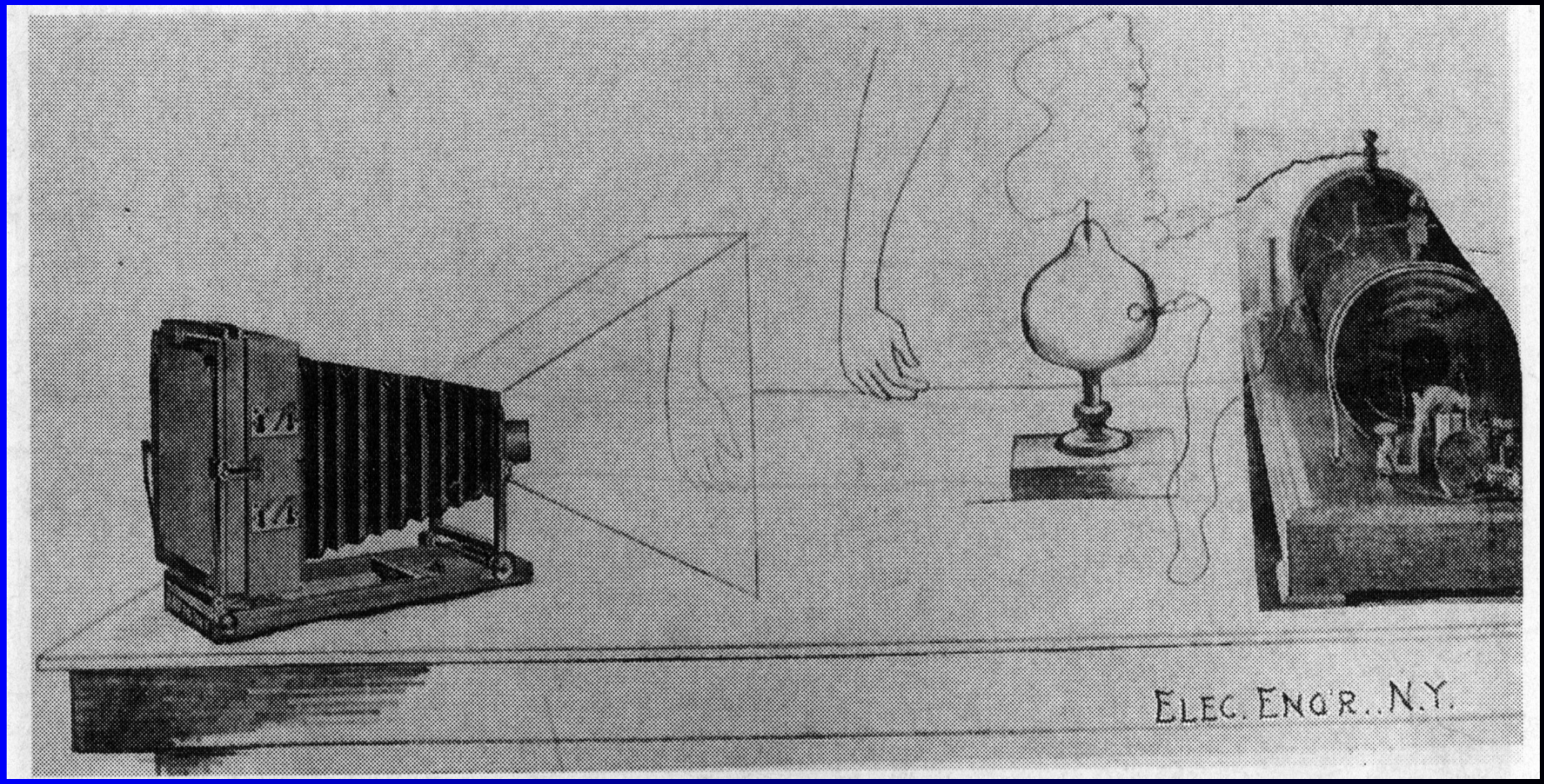
Initial Use of Radiation

- X-rays
  - Medical (diagnostic and therapeutic)
  - Research
  - Commercial
- Radioactive Materials
  - Medical
  - Consumer
  - The “magic” of Radium

Early Portable X-ray Machine



X-ray Fluoroscope



"STANDARD"

RADIUM
PREPARATIONS

"Standard" Radium Solution for Drinking

—

Each bottle contains two micrograms radium element in 60 cc. aqua dist.

—

Maximum-equilibrium constant of radium emanation, 5400 mache units.

PERMANENT

"Standard" Radium Solution for Intravenous Use.

—

In Ampulles of 2 cc. N. P. S. S. containing 5, 10, 25, 50, or 100 micrograms radium element.

PERMANENT

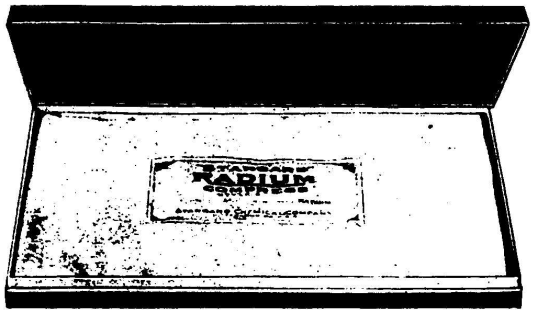
"Standard" Radium Compress

—

A means of applying radium locally for the relief of pain.

—

A flexible pad of standardized, guaranteed radium element content.



PERMANENT RADIO-ACTIVITY

INDICATIONS

Subacute and Chronic Joint and Muscular Conditions.
High Blood Pressure. Nephritis.
The Simple and Pernicious Anemias.

"The value of radium is unquestionably established in chronic and subacute arthritis of all kinds (luetic and tuberculous excepted) acute, subacute and chronic joint and muscular rheumatism (so called) in gout, sciatica, neuralgia, polyneuritis, lumbago and the lancinating pain of tabes."—Rowntree and Baetjer, Journal A. M. A. Oct. 18, 1913.

For Descriptive and Clinical Literature Address

New York
C. Everett Field, M. D.,
50 E. 41st St.

Boston
Samuel Delano, M. D.,
39 Newbury St.

RADIUM CHEMICAL COMPANY

PITTSBURGH

Chicago
C. W. Hanford, M. D.,
719 1st Nat'l Bank Bldg.

San Francisco
Fred L. Lackenbach
Biologic Depot
905 Butler Bldg.

Radium Product

Injuries Reported

- In May 1896 T. Edison reports that eye injuries may be the result of x-ray exposures.
- Skin reddening also appears on both staff and patients.
- Early injuries often ignored because of the latent effect of radiation.
- Physicist and physicians also refuse to believe that x-rays were hazardous.

The World. 66,934

The World's Best July

Edison Fears Hidden Perils of X-rays

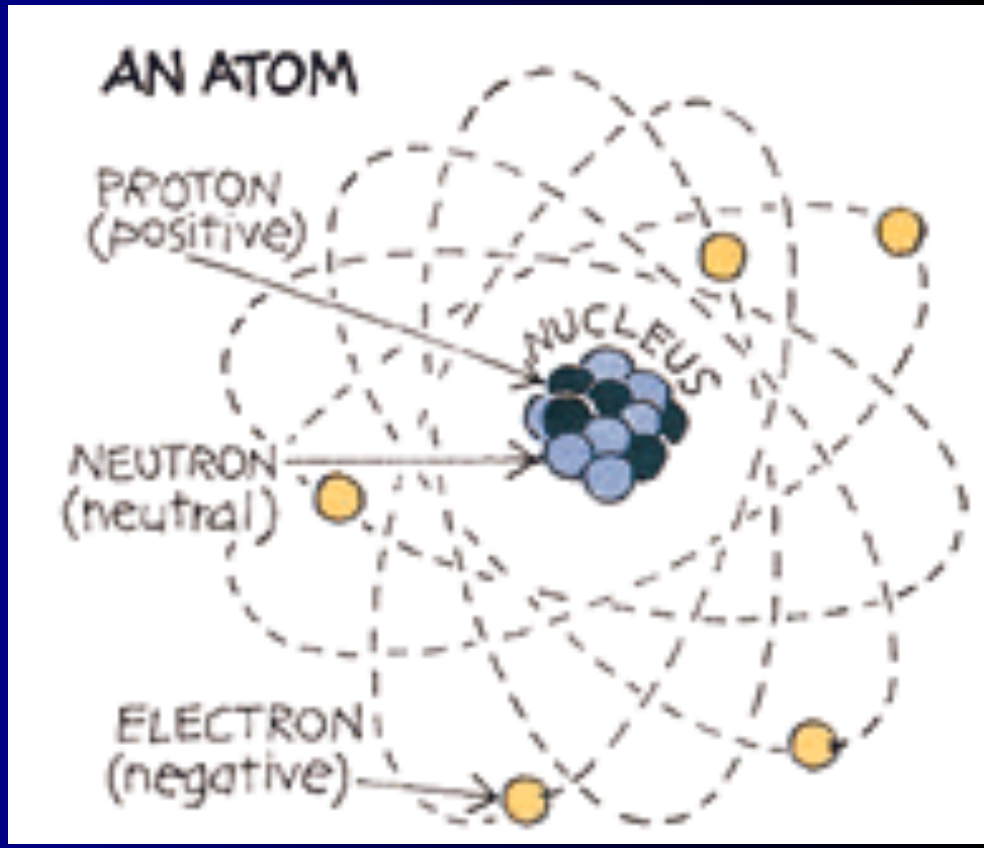
- From New York World, August 3, 1903 page 1.
- Laboratory Employee Loses Hand and Arm
- The circumstances involved the intentional exposure of arms and hands to fluoroscopic resulting in significant injury.
- Edison quits experimenting with x-rays shortly after Dally's death.

First X-ray Attributed Fatality - October 1904

- Clarence M. Dally, a glass blower at the Thomas Edison's Menlo Park Lab, is the first person known to have been killed by x-ray exposure.
- He was severely burned in 1896, he still worked with x-rays until 1898.

The Atom

- Nucleus
  - Protons
  - Neutrons
  - Stability of the nucleus determined by the number of neutrons and protons
- Extra-nuclear
  - Electrons

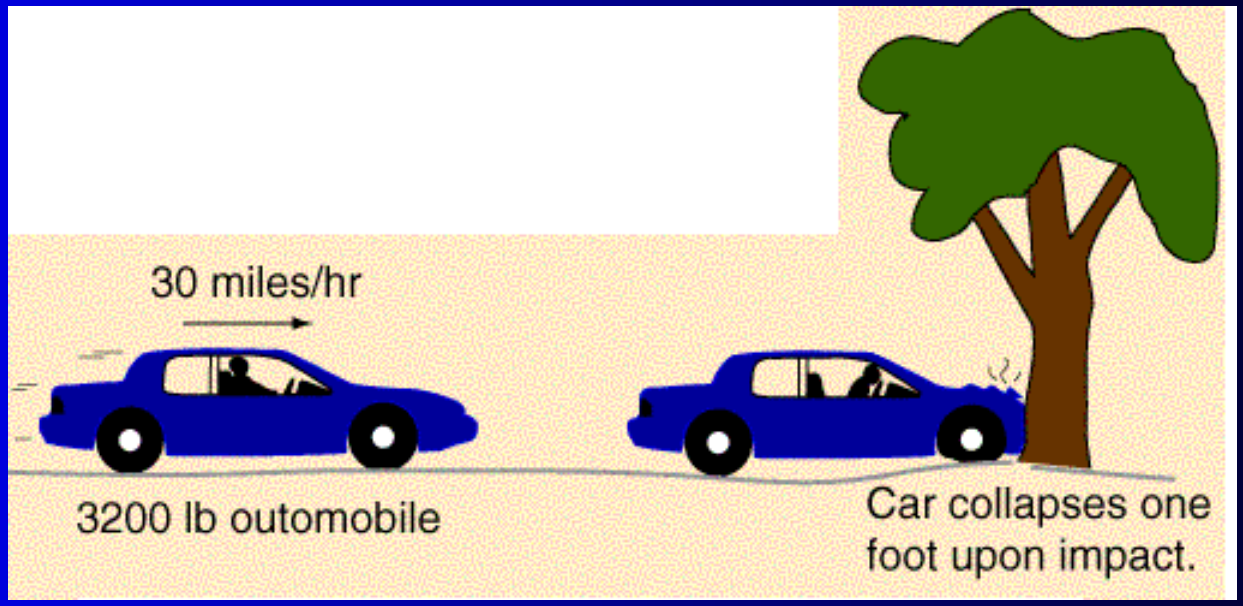


Radioactivity

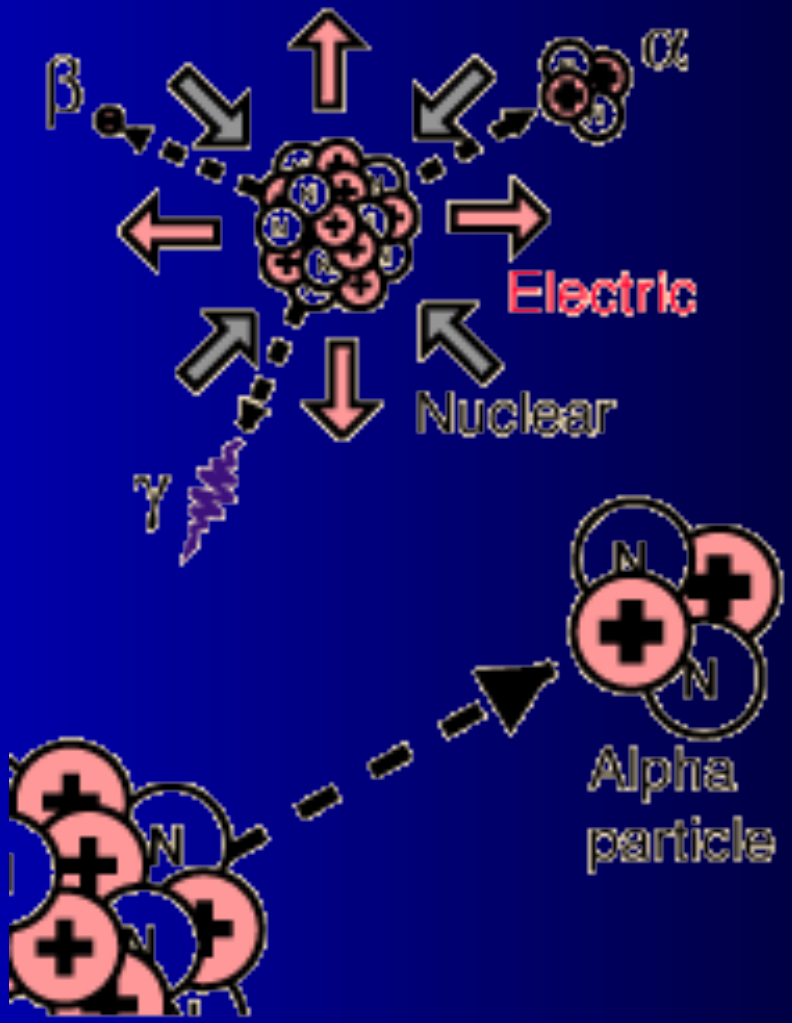
- The transformation of an atomic nucleus from an unstable isotope to a stable isotope
- The instability is due to either too few or too many neutrons in the nucleus of the atom
- The transformation is usually accompanied by the emission of energy which is generally termed radiation.

What is Radiation?

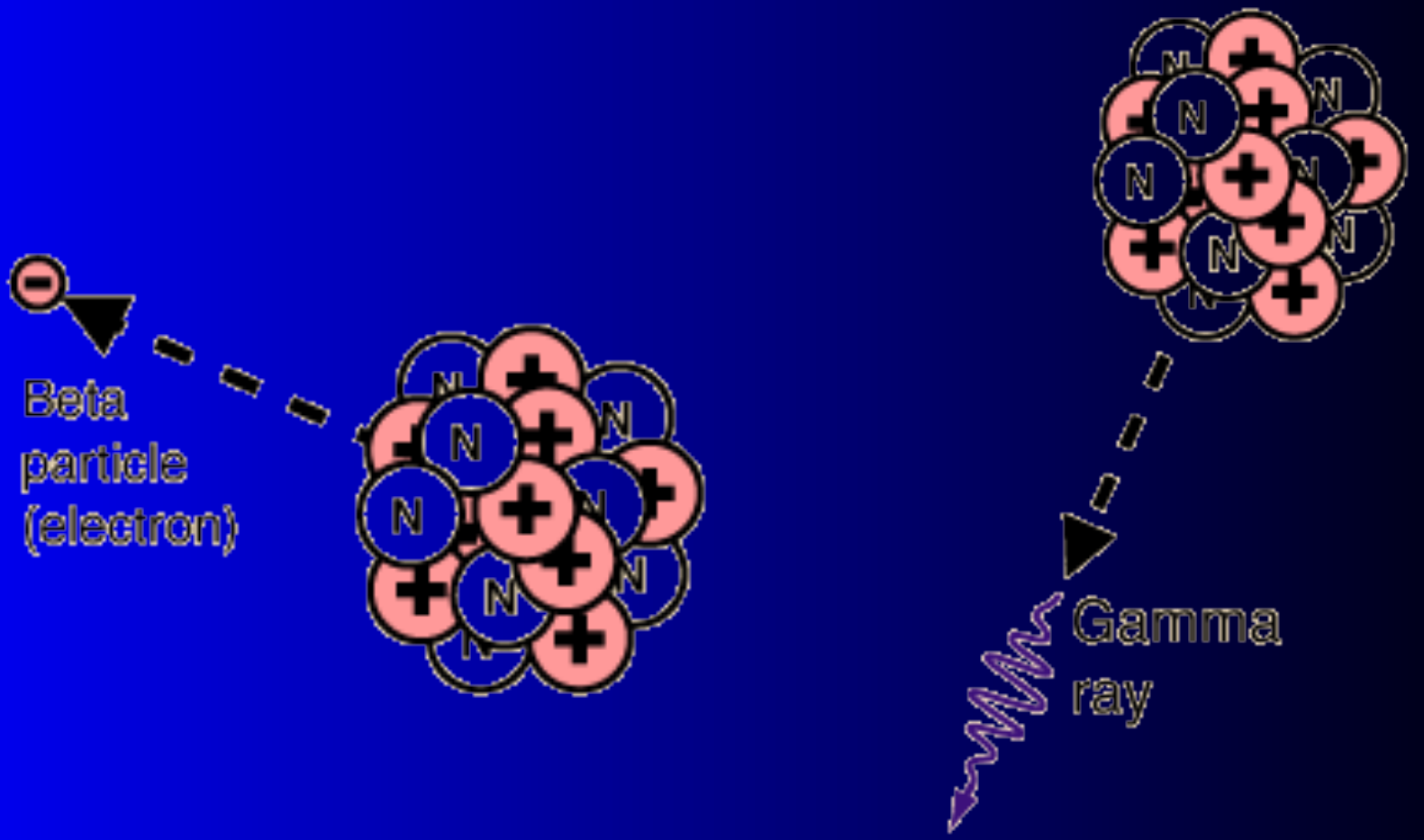
- Transfer of energy from one location to another



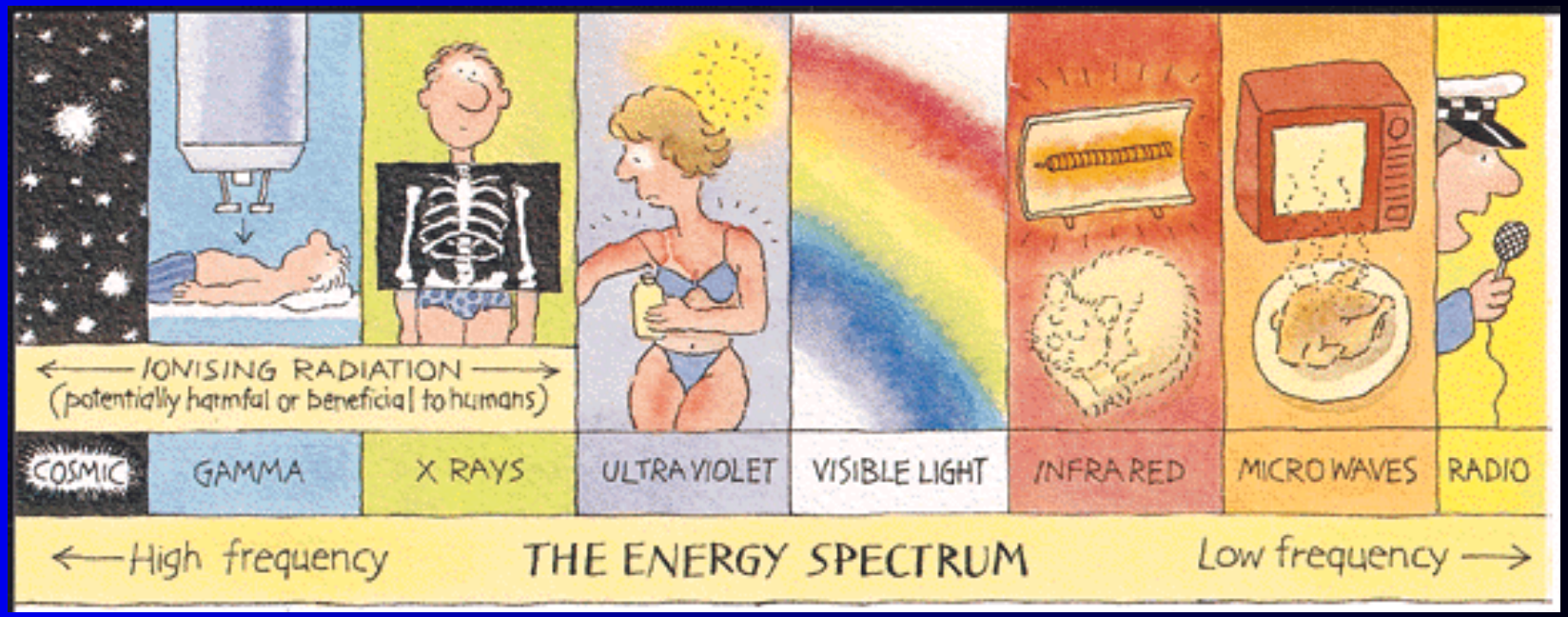
Types of Radiation



Types of Radiation



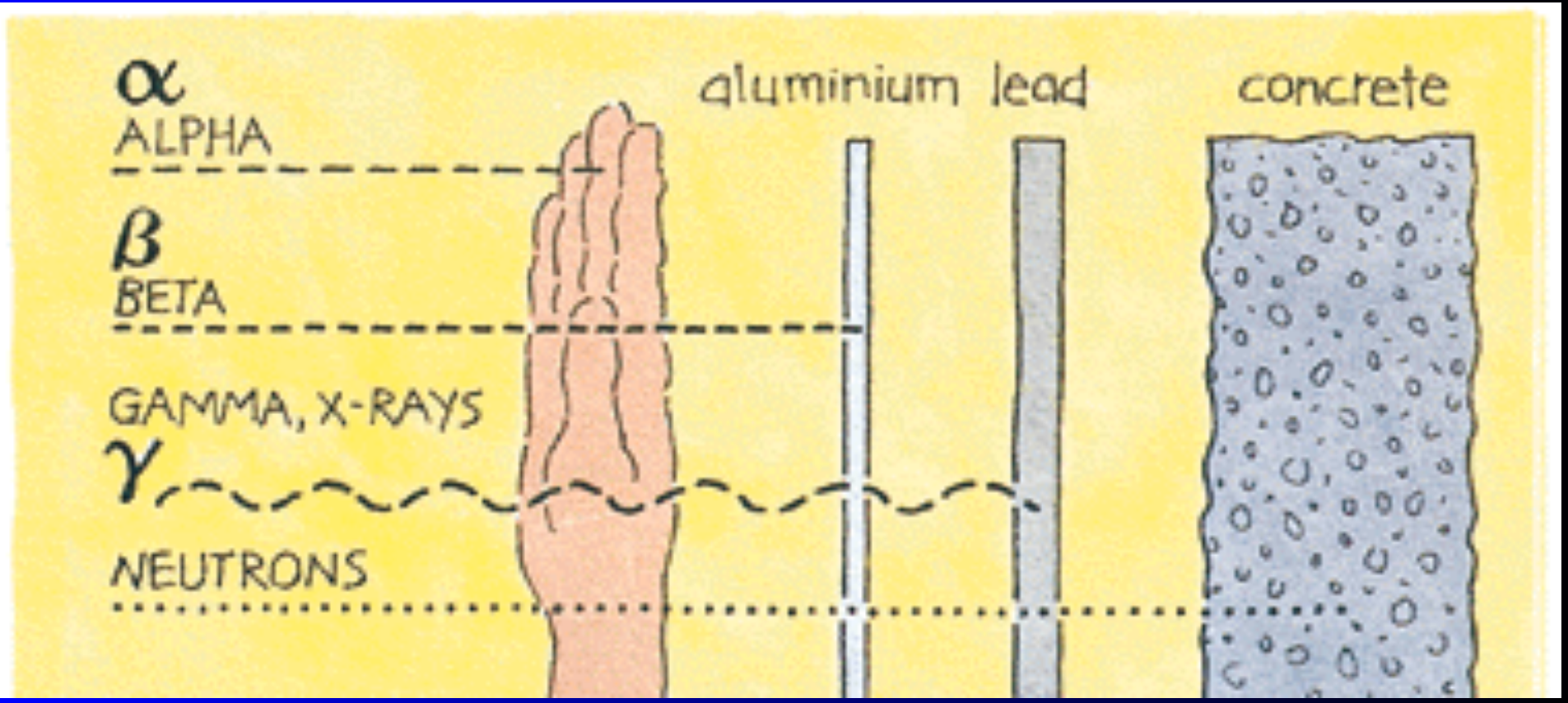
The Electromagnetic Spectrum



Ionizing vs. Non-Ionizing

- Non-Ionizing Radiation
  - Transfers energy by heat conduction
  - No chemical effects
- Ionizing Radiation
  - Has the ability to induce chemical changes
  - Transfers very little energy relative to biological damage

Radiation Penetration



Radiation Safety

- To insure that dose to patients, employees and visitors are kept as low as reasonably achievable.
- Does not mean no dose or zero dose just “safe” dose.

Absorbed Dose

- A measure of the amount of energy absorbed by an object from ionizing radiation.
- Radiation Absorbed Dose (Rad)
- S.I. Unit – Gray (Gy)

Exposure

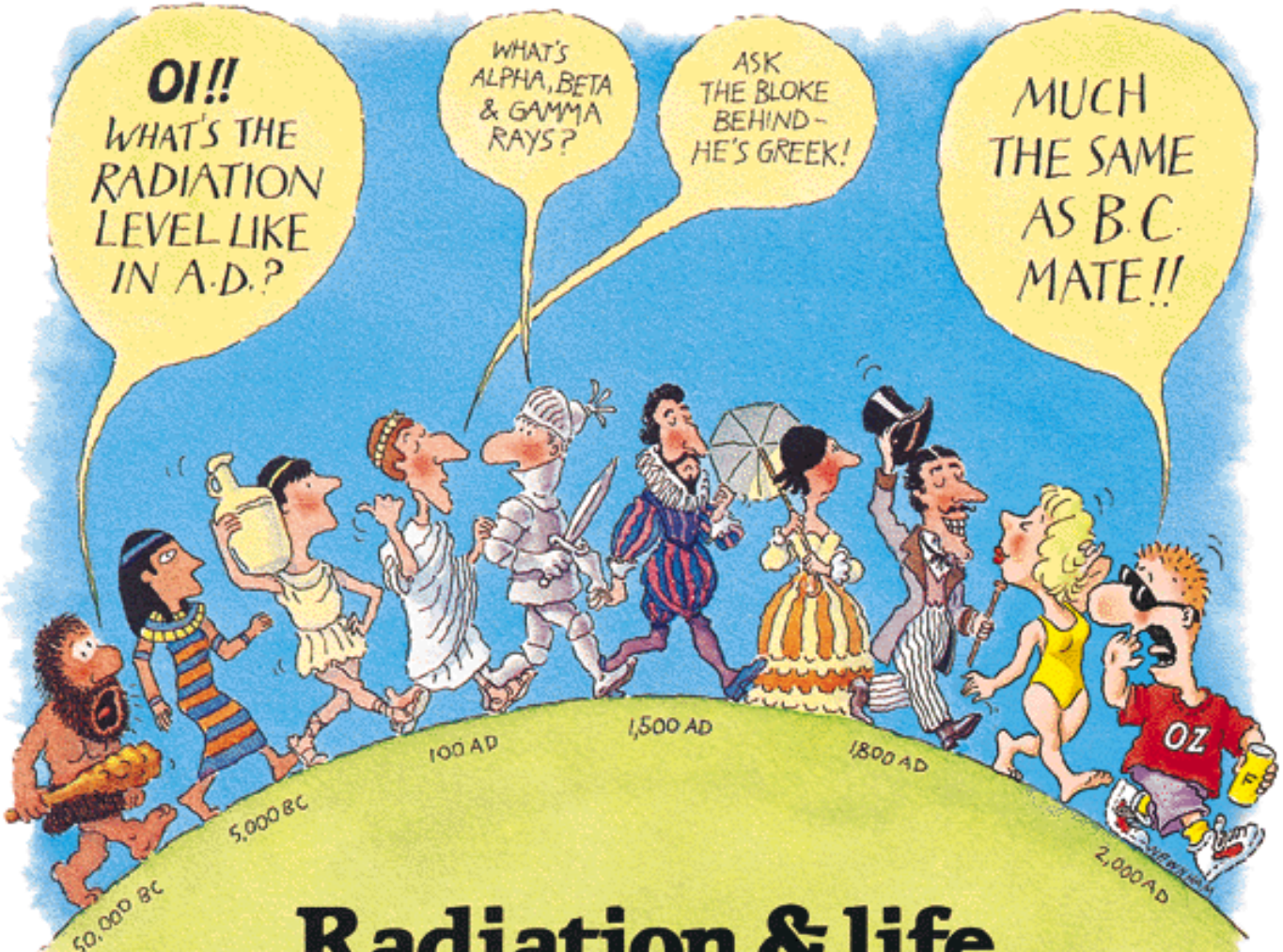
- A measure of the ionizing function of radiation.
- Measures the amount of electrical charge created by x-rays and gamma rays up to 3 MeV of energy.
- Roentgen = 2.54×10^{-4} Couloumbs / kg

Dose Equivalent

- A measure of the biological effectiveness (the amount of biological damage) of a given type of radiation.
- Determined by taking the absorbed dose and multiplying it by an adjustment factor for biological damage
- Rem (Roentgen Equivalent Man)
- S.I. Unit – Sievert (Sv)

Activity

- A measure of the number of transformations occurring in a given amount of material.
- Is not a complete indication of the radiation hazard
- Curie (3.7×10^{10} disintegrations per second)
- S.I. Unit – Becquerel (Bq) 1 disintegration per second



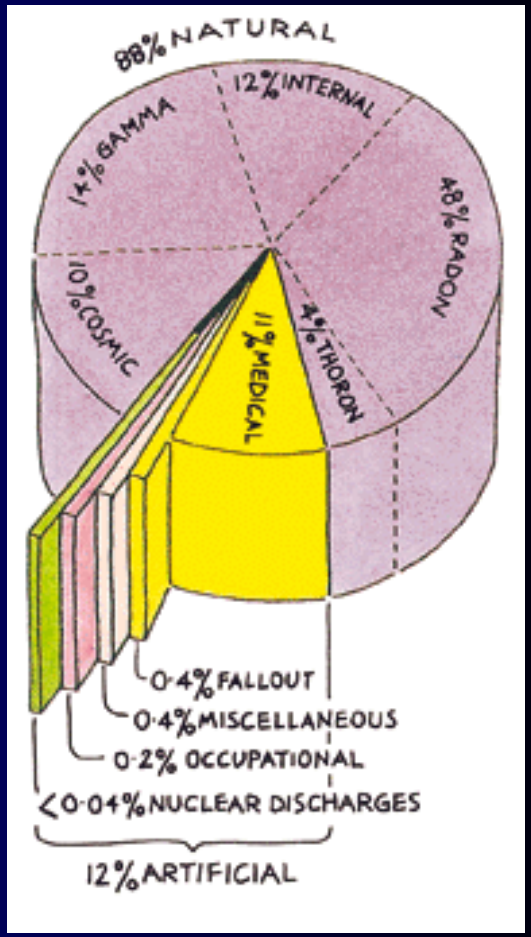
Radiation & life

"Life on earth has developed with an ever present background of radiation. It is not something new, invented by the wit of man; radiation has always been there."

Eric J Hall, Professor of Radiology, College of Physicians and Surgeons, Columbia University, New York. "Radiation and Life".

Sources of Background Radiation

- Natural Radiation
  - ~ 300 mrem/yr (3 mSv/yr)
    - Radon Gas, Cosmic Rays, Uranium, Thorium, Tobacco Products
- Artificial Radiation
  - ~ 60 mrem/yr (0.6 mSv/yr)
    - Diagnostic x-rays, nuclear medicine studies, consumer products, nuclear weapons fallout

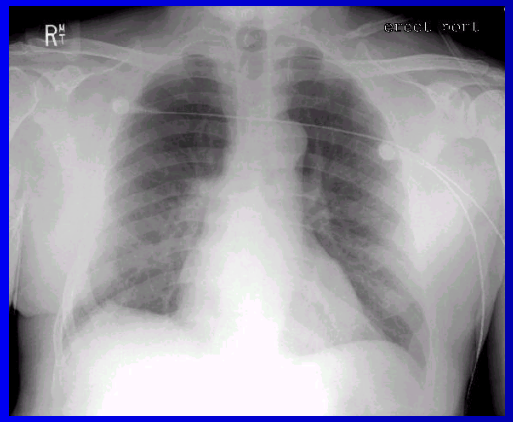


Radiation Detectors

Radiation Exposure from Common Activities

Average US smoker - 16,000 mrem/yr to bronchial epithelia

CT – 100 to 5000 mrem/exam



Chest x-ray 8 to 10 mrem

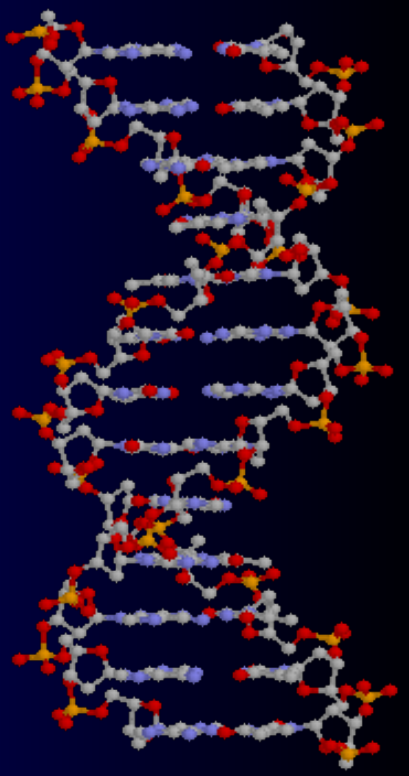
Transcontinental flight from NY to LA 2 to 4 mrem round trip

Astronaut in space for 1 month, 15,000 mrem

Interaction of Radiation in the Body

- Direct interaction with DNA
- Free Radicals (FR): Ionized atoms and molecules
- At diagnostic energies (100 kVp) 95% of interactions of radiation in body generates FRs
- X-RAY + $H_2O \rightarrow H_2O^+$ or H_2O^*
  - H_2O, H_2O_2, H, OH

    (hydrogen peroxide, FR's)



Biological Effects

Biological Effects

- Acute Radiation Effects (exposure to a high dose of radiation over a very short period of time).
- Delayed or Chronic Effects (exposure to low levels of radiation over a long period of time).

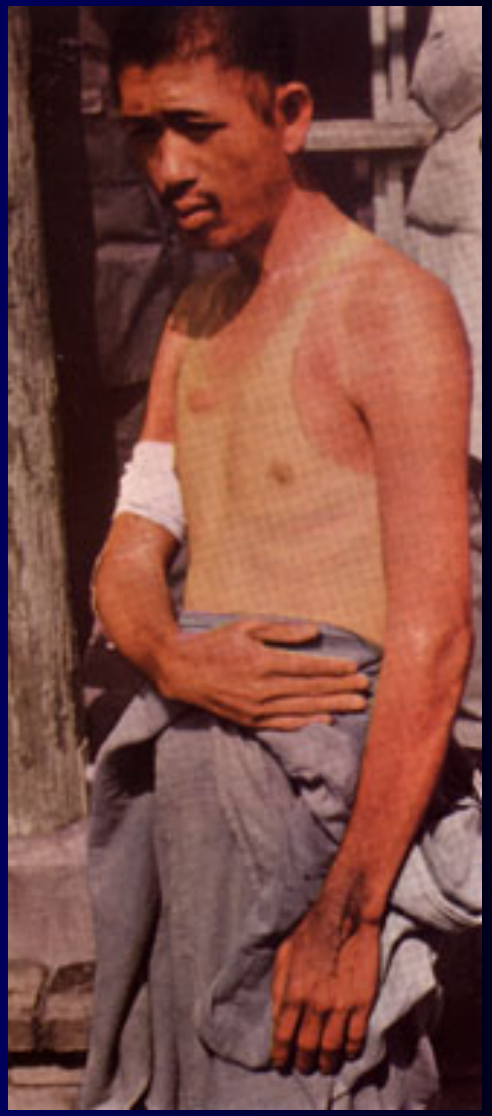
Acute Radiation Effects

Dose in rad	Effect
25-50	Blood count changes
100	Physical Manifestations
200	Bone marrow depression
350	LD 50/30 dose
800	100% Lethal
1000	GI effect
2000	CNS effects

Radiation-Induces Skin Injuries

Effect	Dose (Gy)	Onset Time
Early transient erythema	2	hours
Temporary epilation	3	3 wks
Main Erythema	6	10 d
Permanent epilation	7	3 wk
Dry desquamation	10	4 wk
Invasive fibrosis	10	
Dermal atrophy	11	>14 wk
Telangiectasis	12	>52 wk
Moist desquamation	15	4 wk
Later erythema	15	6-10 wk
Dermal necrosis	18	>10 wk
Secondary ulceration	20	> 6 wk

Some examples of Acute Radiation Effects



Cancer Risk

- The Risk of cancer from exposure to radiation increase with increasing dose for doses above 10 rad.
- The risk from doses below 10 rad are postulated based on statistical analysis. There are no studies that can confirm or deny the effects of dose below 10 rad.

Cancer Risk

- Background cancer risk in the US is approximately 40%.
- 10 mrem of radiation exposure increases cancer risk by approximately 1 in 1,000,000.
- 1 chest x-ray is approximately 10 mrem.

1 in 1,000,000 risks

Driving your car 77 miles in 1999.

Driving a motorcycle 4.3 miles in 1999

Riding a bicycle 10 miles

Eating 1 TBSP of peanut butter.

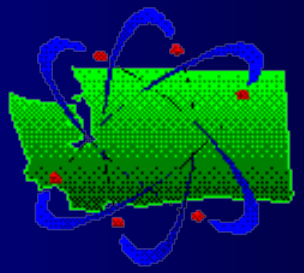
Risks from Everyday Activities

Activity	Fatality/year
Smoking 10 cigarettes/day	1 in 200
Influenza	1 in 500
Playing Soccer	1 in 25,000
Hit by Lightling	1 in 10,000,000
Offshore oil and gas industry	1 in 600
Coal Mining	1 in 6,000
Construction Industry	1 in 7,000
Agriculture	1 in 9,000

Typical Occupational Doses

Category	Annual Dose
X-ray Technologist	96 mrem
Nuclear Medicine Technologist	95 mrem
Flight Crews	170 mrem
Scientist	7 mrem
Nurse	24 mrem
Dentist	70 mrem
Nuclear Power Plant	552 mrem

Dose Limits
Washington DOH



Part of the Body	Annual Limit (mrem)
Whole Body (TEDE)	5,000
Organ or Extremity	50,000
Lens of the Eye	15,000
Dose to Fetus (9 months)	500

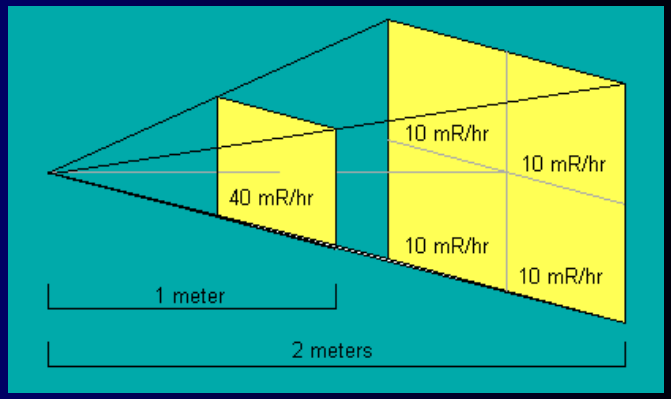
ALARA

- As Low As REASONABLY Achievable
- Reasonable measures are to be taken by facilities to reduce radiation exposure to workers to well below regulatory limits
- Lead Apron, thyroid shield, leaded glasses, appropriate distance when applicable

Radiation Protection - External

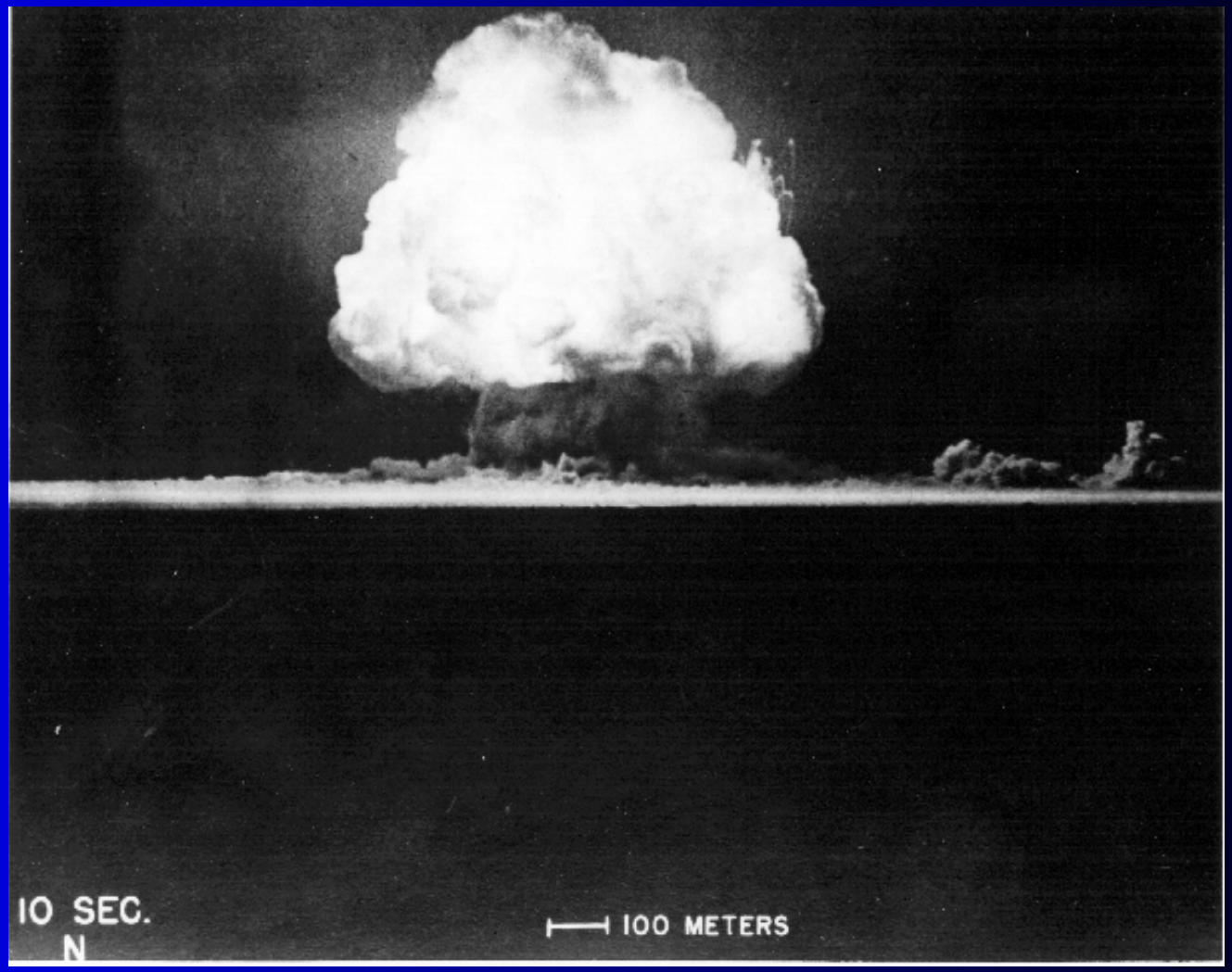
Time - minimize

Distance - maximize



Shielding - lead aprons, lead bricks, etc.

Radiological Emergencies



Types of Radiological Events

- Accidental Release

- Radiological Dispersal Device (RDD)
- Nuclear Device

Accidental Releases

- Still (and hopefully) the most likely radiological event
  - Nuclear power plant release
  - Lost material either industrial sources or medical material
  - Shipping accidents
  - Etc.

Chernobyl

Radiological Dispersal Device

- Conventional explosive device surrounded by radioactive material.
- Radioactivity is generally not great enough to be of a significant hazard to personnel.
- Used primarily as a device to inspire terror and fear.
- The consensus isotopes that would be used are those commonly used for industrial radiography, medical therapy or sterilization

RDD Effects

- Primary Effects
  - Damage from the primary explosive
  - Injuries related to the primary explosive
- Secondary Effects
  - Radiation Exposure from isotope (will generally not be enough to result in physical response)
  - Personnel contamination
  - Area Contamination
  - Fear Factor from potentially unknown radiation exposure

RDD Response

- Efforts will revolve around minimizing contamination, however medical emergencies will take precedence
- The spread of contamination is dependent on the following and hazard:
  - Amount of radioactivity
  - Physical form of material
  - Explosives used
  - Meteorological conditions
  - Type of radioactive material

Nuclear Device

- Anything over a 100 ton yield
  - Hiroshima bomb was approximately 15 kilotons
- Results in significant radiological contamination of both the environment and victims
- Depending on the size of the weapon, those within 300 meters or so will receive not only lethal doses of radiation but also significant physical injuries

Nuclear Device

- Primary Effects
  - Physical Damage from detonation
  - Shockwave
  - Heat Wave (from 1000 meters for a small device up to several miles)
  - Flash burns (individuals)
  - Glass and other projectiles generated by the explosion
  - Radiation and Radioactive Contamination

Nuclear Device

- Secondary Effects
  - Radiation Dose Syndrome Effect from surviving victims
  - Radioactive Contamination
  - High level radiation doses to rescue workers
  - Fallout and prolonged restriction of affected area due to radiation
  - Psychological Impact of Nuclear Weapon usage
- EMP can potentially damage electronic communication adding the logistical issues

Medical Treatments

- Centered around providing supportive care.
- Focus is on patient received radiation doses that are treatable (i.e. considered under 400-500 rad for mass casualties and 800 rad for limited victims)
- Care is centered upon the prevention of infections and minimization of secondary effects.

Radiological Emergency Procedures

- Immediately contact the Radiation Safety Officer
  - Office – 386-2723
  - Pager – 405-7065
  - Home – 367-0711
- All victims will arrive via the emergency department
- Washington DOH Hotline
  - 1-800-NUCLEAR

HEICS

- For hospitals, HEICS will be initiated.
- Incident Command with consultation of the Radiation Safety Office providing expert consultation and coordinating the individual performing environmental risk analysis.
- Radiation Dose Limits will be followed along with recommended action guides from the DOE and EPA.
- Monitoring with portable instruments, instant read dosimeters and film badges.

EPA Action Guidelines

Dose limit (whole body)	Emergency Action Dose Guidelines Activity Performed
5 rem	All Activities
10 rem	Protecting major property
25 rem	Lifesaving or protection of large populations
>25 rem	Lifesaving or protection of large populations. Only by volunteers who understand the risks.

DOE Dose Rate Recommendations

Dose Rate	Recommended Actions
x2 Background	Contaminated Persons
1 – 5 mR/h	Hot Line (i.e. separate and decon)
0.001 – 10 R/h	Work in Hot Zone (personnel)
10 R/h	Turn Back (except for lifesaving)
200 R/h	Turn Back (even for lifesaving)

Personnel Monitoring

- Film Badge Dosimeters
  - No immediate read, will primarily be used in situations where immediate results are not required
- Pocket Dosimeters
  - Immediate read
  - Not as accurate as Film Badge Dosimeters

Summary

- Radiation Exposure is a part of everyday life
- Physiological Effects from radiation do not occur at levels below the annual occupational dose limit
- There are two principal radiological events in the news today
  - Radiological Dispersal Device
  - Nuclear Device

Summary

- Generally speaking medical intervention should always take precedence over decontamination
- Radioactive contamination hazards are only of significant physiological concern with Nuclear Devices.
- In an emergency contact 206-NUCLEAR

Questions

- John Gough, MS, CHP
  - Radiation Safety Officer
  - Swedish Medical Center
  - 386-2723 (office)
  - 405-7065 (pager)